

## NTR PLUME MODELING

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### COMPUTATIONAL FLUID DYNAMICS (CFD) FOR PLUME ANALYSIS

#### MOLECULAR FLUID MECHANICS

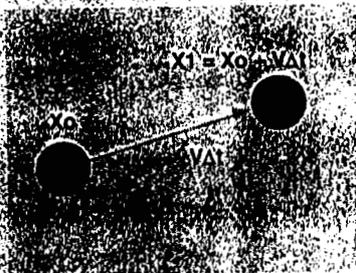
- THE VAST MAJORITY OF CFD DEALS WITH GASES WHICH ARE ADEQUATELY DESCRIBED BY THE CONTINUUM THEORY, I.E., THE NAVIER-STOKES EQUATIONS.
- IN RAREFIED GAS FLOWS, A MOLECULAR MODEL IS APPROPRIATE, REQUIRING DIFFERENT TECHNIQUES.
  - DIRECT SIMULATION MONTE-CARLO (DSMC)
  - FINITE DIFFERENCING OF THE BOLTZMANN EQUATION
- MOLECULAR CFD IS REQUIRED FOR:
  - NOZZLE LIP AND CRITICAL BACKFLOW REGIONS
  - PLUME / SPACECRAFT INTERACTIONS
  - GROUND TESTING

MOLECULAR CFD CHARACTERISTICS

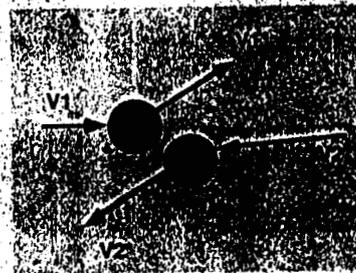
- DSMC TECHNIQUES TRACK A LARGE NUMBER OF MOLECULES (OF ORDER  $10^5$  TO  $10^7$ ) AND MODEL THEIR INTERACTIONS STATISTICALLY.
- COMPUTATIONALLY INTENSIVE
- DR. CHAN-HONG CHUNG HAS DEVELOPED AN ENHANCED DSMC CODE WITH MULTI-SPECIES CAPABILITY, ALLOWING MORE ACCURATE CALCULATIONS OF SPECIE SEPARATION.

**DIRECT-SIMULATION MONTE-CARLO (DSMC) METHOD**

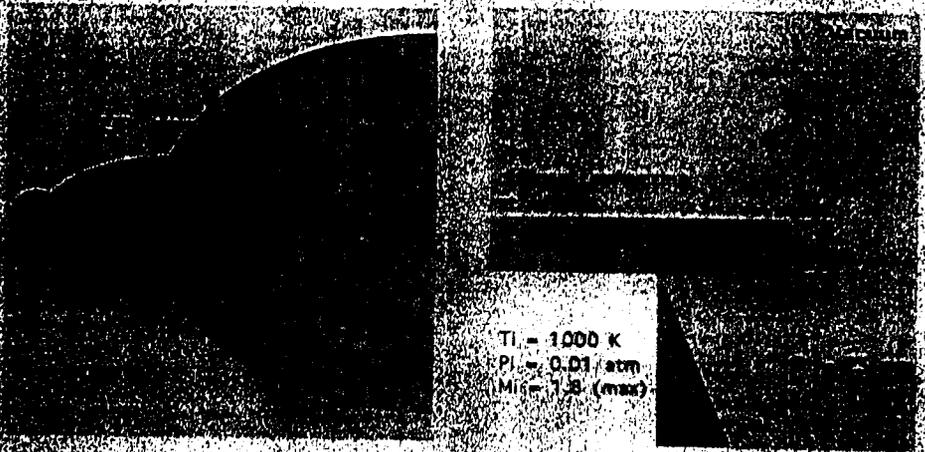
A computer technique to model low density gas flows by concurrently following the motion and intermolecular collisions of representative molecules



**Molecular movement**



**Molecular collision**



**SIMPLIFIED NOZZLE LIP**

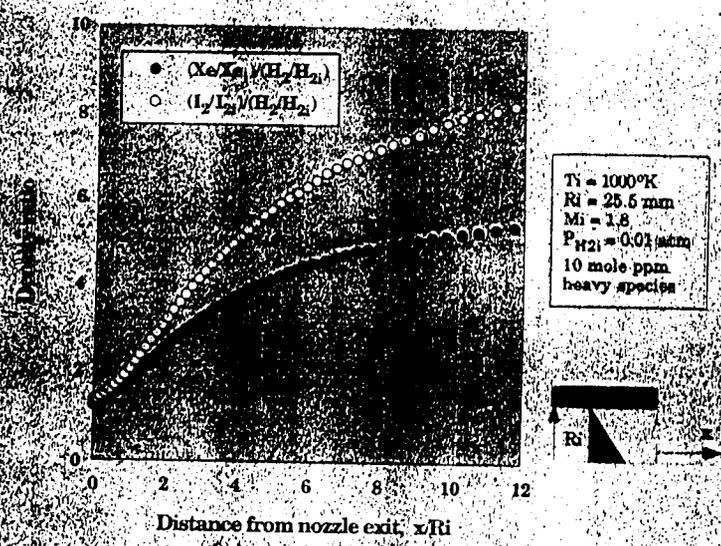


Fig. 2 Effect of molecular weight on species separation along bottom plane

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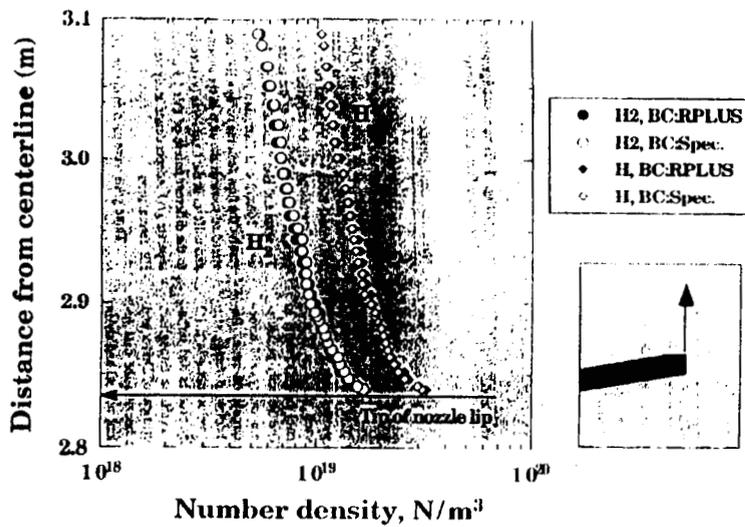
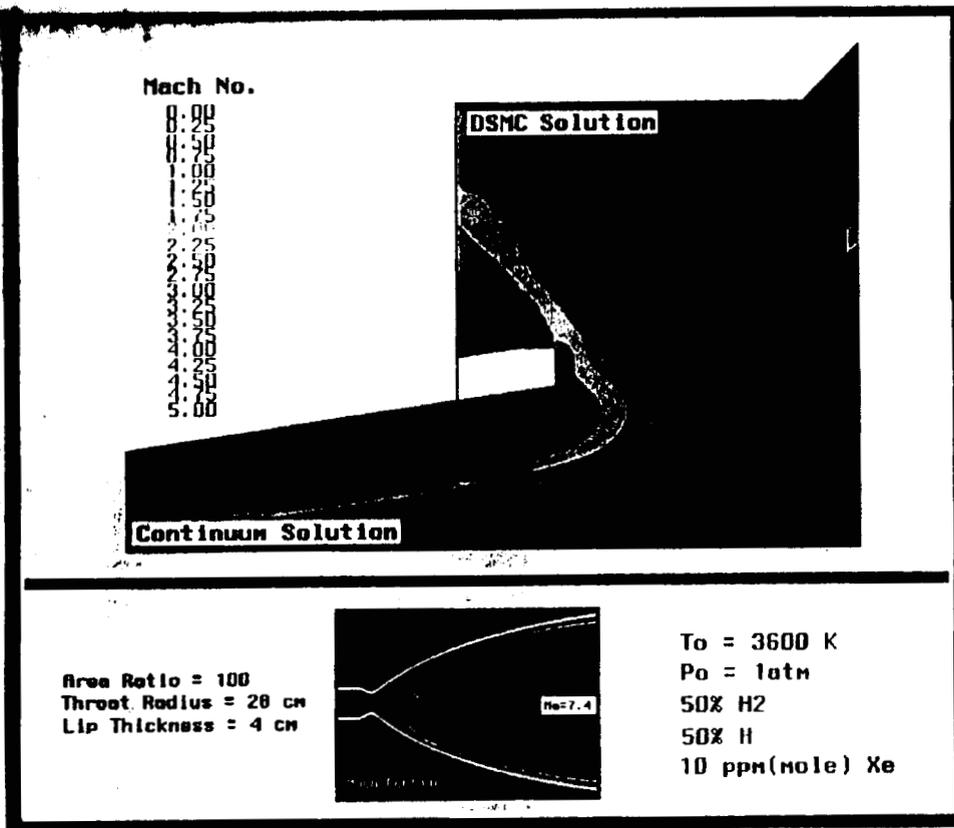


Fig.1 Density profile along the line parallel to exit plane

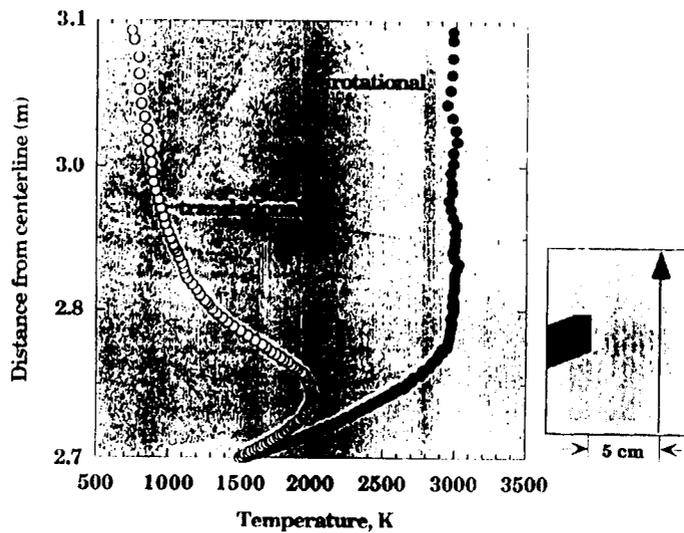
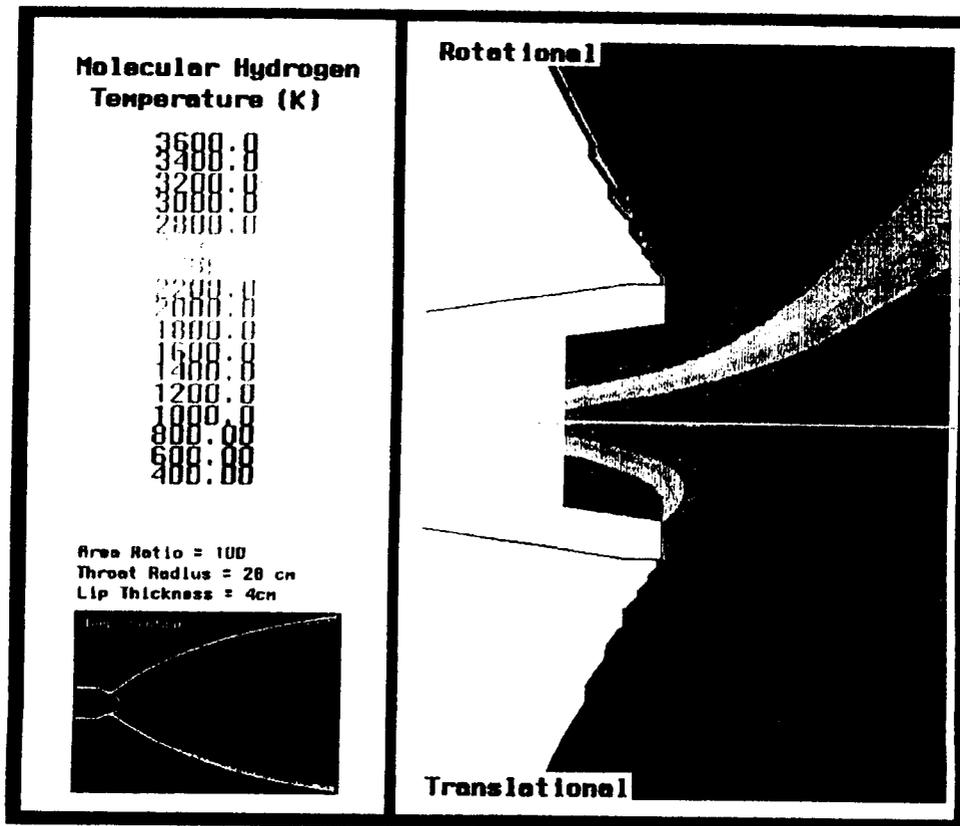
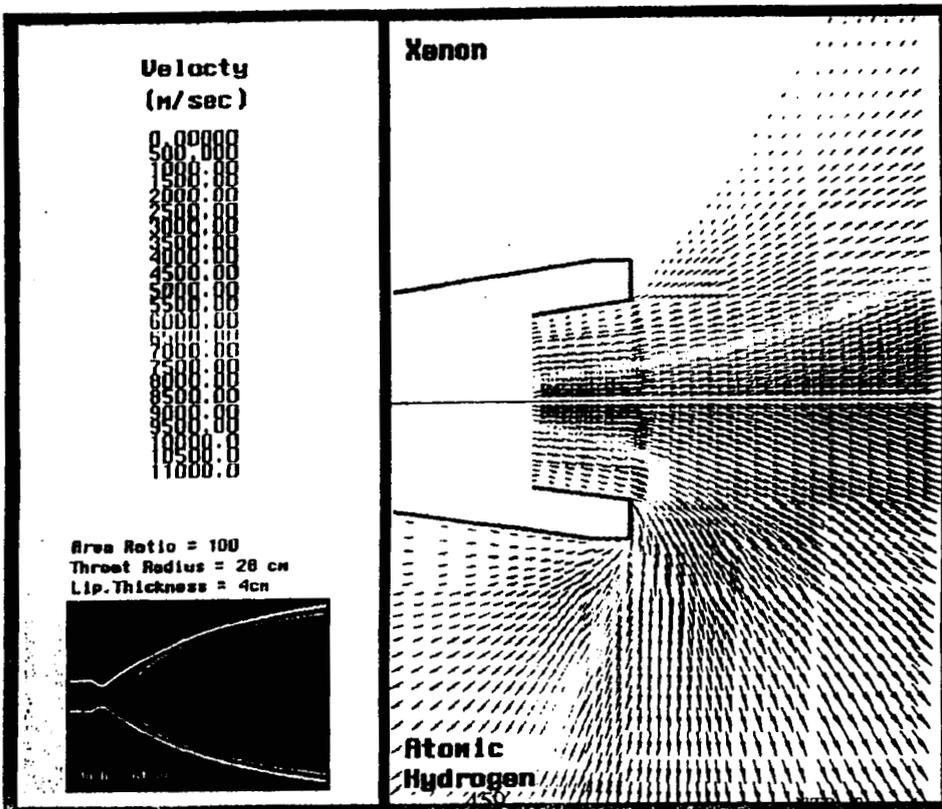
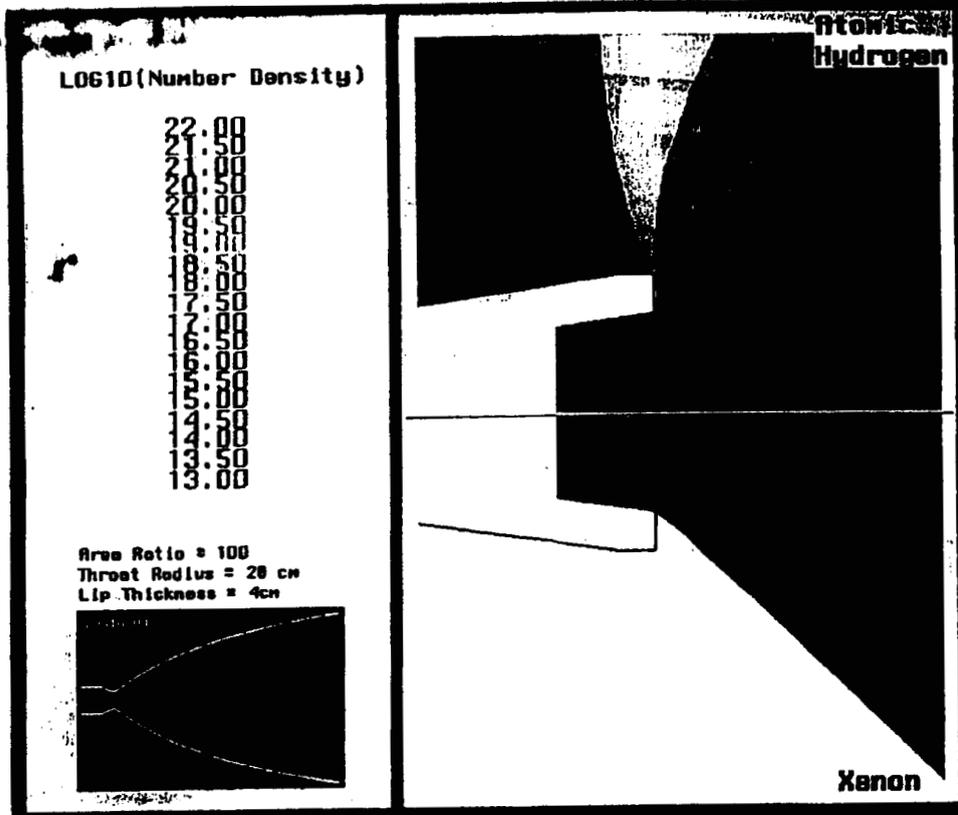


Fig.4 Molecular hydrogen temperature profile along the line parallel to exit plane



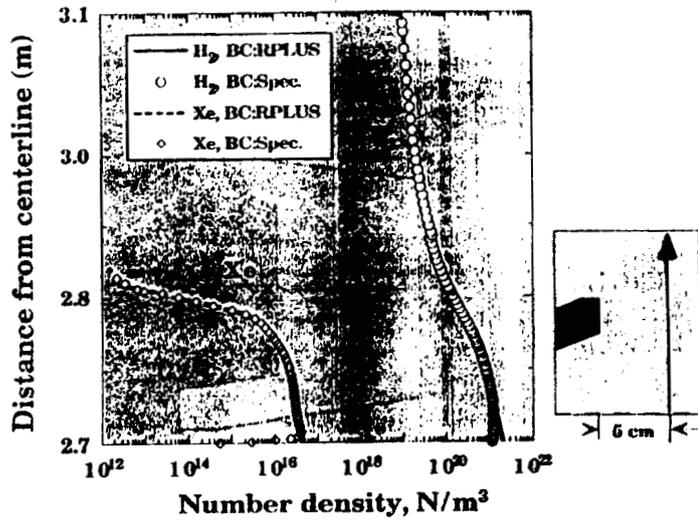


Fig.2 Density profile along the line parallel to exit plane

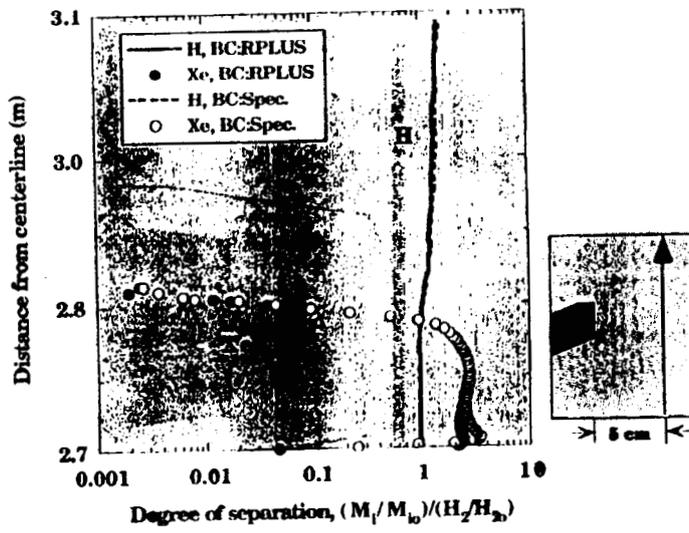


Fig.3 Degree of separation along the line parallel to exit plane